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Water Treatment with Combination of RO and IX Separation Technology

Innovative water treatment technology

LANXESS has developed a new water treatment technology. The new technology involves the state-of-the-art plant as well as advanced software to complete the solution.

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For quality assurance purposes each individual Lewabrane module is checked in an element tester at the LANXESS site in Bitterfeld Germany

Water treatment in today's modern world requires highly technical, high performance separation products to achieve increasingly stringent treated water qualities, or to provide the lowest cost of water production. To achieve the demanded quality, often, more than one separation technology is applied. This development was a main consideration for Lanxess to start production of Lewabrane reverse osmosis (RO) membrane and elements at a new production site in Bitterfeld, Germany.

RO treatment

The dominant RO membrane structure is based on a thin film composite membrane. The barrier (or rejection) layer is a 0.1µm thick polyamide layer, which is supported by a polysulfone substructure. The polyamide layer is formed by a polymerization process.

Although thin film composite membranes based on this process have been used for more than thirty years, the newest technology offers the possibility to control the polymerization process more precisely. Accordingly, a strong focus of the company's membrane development was the enhanced polymerization degree of the polyamide layer. A higher polymerization degree improves the mechanical and chemical stability of the thin barrier layer offering greater durability. Additionally, the negative charge on the membrane surface is reduced, which leads to a lower cationic adsorption (fouling) on the membrane surface.

Due to its chemistry, the surface of a polyamide membrane is usually negatively charged, and often results in cationic fouling that is extremely difficult to remove. A typical example for cationic fouling is the fouling with iron. Iron chloride ($FeCl_3$) is a very common flocculation chemical used in pretreatment systems. If the dosing is too high, even just for a short period, the cationic fouling can irreversibly foul the RO membrane surface. Apart from a well adjusted iron chloride dosing system, a lower negative surface charge is the best option to reduce the fouling potential of this event.

The membrane separation composite layer is the most essential part of the RO separation process. Before use, this critical component is assembled into a device, called an RO element. The winding process for spiral wound RO elements involves many steps all of which need to be carefully controlled. The company's manufacturing process involves state-of-the-art robotic equipment to carefully prepare the RO element to exacting mechanical specifications. Much of this development was conducted with the assistance of outside institutes who applied modern computer aided design capabilities to confirm mechanical strength and optimize hydrodynamic design (see Figure 2). This kind of critical development process was necessary to assemble the improved membrane chemistry into a modern RO element.

Innovation

The first field tests of the new Lewabrane RO B400HR elements started in January 2012. The elements were placed in an existing RO plant, which is treating 40m^3/hr of Rhine river

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water after an ultrafiltration system. A total of six elements were installed in a pressure vessel. The RO system also contained several pressure vessels with RO elements from another supplier. These elements were installed approximately one year prior, and were operated in parallel to the Lewabrane pressure vessel. The entire RO system was operated in a two stage system with a 6:3 array using six element pressure vessels.

In comparison with the installed elements from another supplier, it could be shown that the Lewabrane elements provided a flux value in the same order of magnitude. The TOC and silica rejection were measured periodically during field testing. The TOC rejection was measured at approx 95-96 per cent, and the rejection of the total silica was measured at approx 99.3 per cent. In conclusion, it was demonstrated that the new Lewabrane RO membrane element performs in a similar manner under the same operating conditions.

The reason that the company undertook the big step in adding RO membrane technology to its separation products portfolio is that reverse osmosis is a complementary technology to the ion exchange (IX) resins. The ion exchange resins have been produced for more than 70 years under the brand name Lewatit. As a general rule, reverse osmosis can efficiently desalinate water with high salinity, but ion exchange can selectively remove certain ions from the water. Table 1 shows that depending on the requested permeate quality, which separation technique could be used.

In modern separation applications, combined RO and IX processes are not only used in applications like the desalination of boiler feed water, but in other process applications like the removal of boron from sea water, or the treatment of produced water from unconventional gas resources. These applications have recently been under much discussion because of increasing public concern for water quality and environmental considerations.

Reverse Osmosis — Membrane Chemistry and Functionality

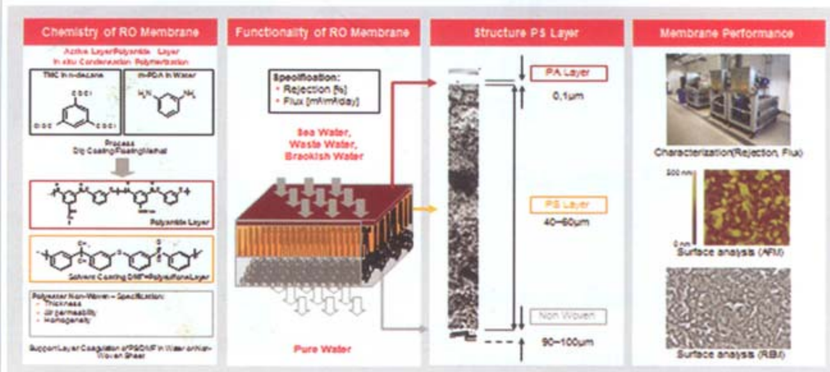

Figure 1: Structure of a thin film composite membrane

Source: LANXESS

Treating water in gas production

The production of gas from unconventional sources is growing rapidly worldwide. Water that comes up along with the gas is not only challenging to treat, but must often meet strict regulatory standards prior to release into the environment. Such regulations pose challenges to water treatment system designers. While varying significantly, typical waters may have a TDS range of 2,500 – 10,000 mg/l, total alkalinity of 1,000 – 3,000 ppm as $CaCO_3$, and a pH in the order of 8-9. Since most inland areas are sensitive to the discharge of salts, the concentrate from a water treatment process will require specialized disposal. Therefore, minimizing the volume of waste concentrate is paramount to the success of the application. RO processes with a high recovery rate and low usage of chemicals are one solution. To achieve this goal, softening with IX as pretreatment and inter-stage treatment for a three stage, single pass RO unit is one option.

TABLE 1

PROCESS	DEMINERALIZATION	DESALINATION
Limits	Conductivity <2 µS/cm TOC <500 ppb SiO_2 <50 ppb	Conductivity <0.055 µS/cm TOC <100 ppb SiO_2 <10 ppb
Technology	Ion Exchange Reverse Osmosis Electrodialysis	Ion Exchange (mixed bed) Electrodeionization (EDI)

Recovery

In order to achieve high recovery, softening down to ppb levels of hardness is required. To achieve this reliably, particularly for high salinity water, a selective IX process is used. One example of this is the weak acid cation resin type (for example, Lewatit CNP80), which is typically used prior to the RO treatment for brackish waters. Another example is chelating resins, which are able to effectively soften to ppb levels, even from saturated brine solutions. This type is typically used to soften the concentrate from an RO plant, ahead of further RO treatment. An iminodiacetic acid chelating resin (for example, Lewatit MonoPlus TP208) is typically selected when strontium and barium removal is important; otherwise an aminophosphonic acid resin (for example, Lewatit MonoPlus TP260) is preferentially used.

In most applications a chemical treatment with acids or antiscalant is used as pretreatment for an RO process. The softening process with IX has advantages if, like in the example above, the discharge of salts is difficult, or if the solubility products (Ksp) of the salts are far above the saturation limit so that an antiscalant cannot be used for the application.

Boron removal

In contrast to the produced water treatment example above, IX is used as a post-treatment for boron removal. Boron removal with RO alone is done at pH 9. At this pH, the Boron is

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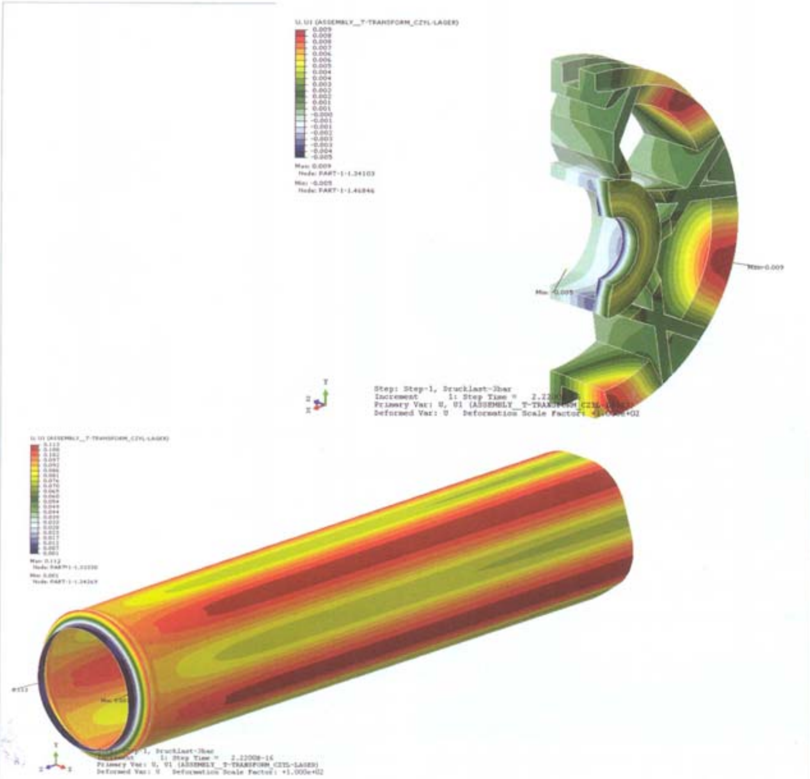

Figure 2: Stress test on the Anti telescoping device (ATD) and permeate tube

partially negatively charged and the rejection can be up to 90 per cent with Seawater RO, and 75 per cent with Brackish water RO elements. To achieve a limit of below 0.5 mg/l Boron in the permeate, an additional RO treatment of the first permeate is necessary (via 2 pass, or partial two pass system). The pH adjustment is done in front of the second pass in such a case.

An alternative for this process is a post treatment with IX. Although only a few plants are installed with this technique, this process has some clear advantages if the customer requests a low Boron concentration (0.3 mg/liter). In a pilot test of a seawater desalination plant the Boron level could be reduced from 0.7 mg/l (after RO) to 0.2 mg/l (operating capacity of 2.6 g/l). Since IX is a separation process with high selectivity, mainly Boron is removed and the capacity of the resin is not exhausted by other ions. Similar processes can be used to remove other critical compounds selectively after an RO process, like arsenic or heavy metals.

Software

Most engineers use customized software from product manufacturers to design IX or RO systems. The company has designed new comprehensive software, designated LewaPlus. This software can calculate RO and IX arrays inside the same software. As a consequence, water treatment plants with a two pass system or hybrid processes using RO followed by IX can be compared, allowing the designer to quickly optimize

TABLE 2: Saturation level of salts where antiscalant cannot be used

SCALE FORMING COMPOUND	CONSERVATIVE SATURATION LEVEL
$CaSO_4$	230%
$BaSO_4$	6,000%
$SRSO_4$	800%
SIO_2	150% (OR 200PPM)
$CACO_3$	LSI > 1.8, SDSI >1.0

the water treatment plant. Additionally, the effects of process variables, like temperature, can be calculated and assessed for a whole system.

When designing an RO plant, the software offers the possibility to get a recommended array based on the information which has been entered. Further updates are planned this year, for example the option for post-treatment with IX, and a detailed cost and energy calculation for the RO design.

In making an economic validation of RO and IX processes, the cost of discharging the concentrate is often important. However, the salt concentration of the feed is usually of primary interest. While the specific costs for demineralized water using IX is dependent on the salt concentration of the feed water, the specific cost for an RO plant is constant for a broad range of salt concentrations. Secondly, the specific costs of the RO treated water are starting at a higher level so that the breakeven point (intersection) shows the designer where the salinity value of IX and RO have the same costs.

Apart from the economic validation other reasons may appear as to why a RO or IX is selected for a process. In general, RO process is preferred if easy handling is a critical selection issue while IX is preferred if high selectivity is beneficial.

Process solutions

LANXESS believes that both IX and RO technologies will continue to strongly grow in the near future. Seawater desalination is rapidly growing with an expected growth rate of 12 per cent; brackish water at a slightly lower growth rate. The RO membrane process clearly has a bright future. And, with water treatment processes, demanding greater efficiency IX has a bright future. The modern technology of water treatment requires the combination of several technologies, for example, the integration of different membrane processes (e.g Ultrafiltration and RO membrane separation) or the combination of several techniques like RO and IX, or RO and EDI.

LANXESS now offers two state-of-the-art process solutions (RO and IX) to allow the process designer to optimize the water treatment process with the goal of a lower cost and higher reliability of water treatment for the user.